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# XIII.

## CONTRIBUTIONS FROM THE PHYSICAL LABORATORY OF THE MASSACHUSETTS INSTITUTE OF TECHNOLOGY.

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## No. II.—LIGHT TRANSMITTED BY ONE OR MORE PLATES OF GLASS.

By W. W. Jacques.

Read, April 13, 1875.

The following experiments were made for the purpose of determining the percentage of light transmitted through 1, 2, . . . , 10 plates of glass, normal to the direction of the light, and of one, four, and ten plates when $i$ was 0°, 5°, . . . , 65°.

The apparatus used consisted of a triangular frame, isosceles and right angled, having a periphery of 100 inches. A gas jet was placed at the right angle, and two mirrors were so placed at the other angles as to reflect the light from the jet along the hypothenuse, thus giving the effect of two equal sources of light 100 inches apart. The plates of glass were mounted on a graduated circle placed between the jet and one of the mirrors, and the light cut off was measured by a Bunsen disc, movable along the hypothenuse of the triangle. (See "Physical Manipulation," Expt. 67. Pickering.)

The plates used were of common 12 × 18 window glass, and were carefully cleaned with rotten-stone, and then dried by rubbing with chamois skin immediately before each experiment.

The experiments were made in a dark room, whose walls were painted black, and it was found that the reflection from a sheet of paper, or even from the clothes of the observer, was sufficient to prevent the accurate setting of the disc. The following tables give the results of the experiments; each number being the mean of four observations, and the probable error of a single observation being 0.42 of one per cent.

Table I. gives the percentage of light transmitted by 1, 2, . . . , 10 plates when $i = 90°$. The first column gives the number of plates, the

TABLE I.

| Plates. | Observation. | Theory. | Difference. |
|---|---|---|---|
| 0 | 100 | 100 | .0 |
| 1 | 89.5 | 89.5 | .0 |
| 2 | 81.3 | 81.1 | .2 |
| 3 | 74.7 | 74.1 | .6 |
| 4 | 69.3 | 68.2 | 1.1 |
| 5 | 64.0 | 63.2 | .8 |
| 6 | 60.0 | 58.9 | .1 |
| 7 | 55.0 | 55.1 | —.1 |
| 8 | 52.0 | 51.8 | .2 |
| 9 | 48.3 | 48.8 | —.5 |
| 10 | 45.3 | 46.2 | —.9 |

second gives the observed amount of light transmitted, the third gives the amount transmitted as calculated by the formula $t = \frac{1-A}{1+(m-1)A}$, in which $A$ is the amount reflected from one surface, and $m$ the number of surfaces. The quantity $A$ was determined by solving the equation $t = \frac{1-A}{1+A}$, in which $t$ was carefully determined by a considerable number of observations. The fourth column gives the differences between the observed and computed values, which are within the limits of errors of observation. It will thus be seen that these observations give a very accurate proof of the above formula.

TABLE II.

| $i$. | One Plate. | | Four Plates. | | Ten Plates. | |
|---|---|---|---|---|---|---|
| | Obs. | Theor. | Obs. | Theor. | Obs. | Theor. |
| 0° | 89.5 | 91.2 | 69.3 | 71.7 | 45.3 | 50.6 |
| 5° | 89.7 | 91.2 | 69.3 | 71.7 | 45.0 | 50.6 |
| 10° | 89.5 | 91.1 | 69.3 | 71.7 | 44.5 | 50.7 |
| 15° | 89.3 | 91.1 | 69.3 | 71.7 | 44.5 | 50.8 |
| 20° | 89.0 | 91.1 | 69.0 | 71.8 | 44.7 | 50.9 |
| 25° | 89.0 | 91.1 | 69.3 | 71.8 | 44.7 | 51.0 |
| 30° | 88.5 | 90.9 | 68.7 | 71.9 | 45.0 | 51.6 |
| 35° | 87.7 | 90.6 | 68.7 | 72.0 | 46.7 | 52.4 |
| 40° | 87.5 | 90.0 | 68.5 | 72.1 | 48.3 | 53.8 |
| 45° | 86.3 | 89.4 | 68.3 | 72.1 | 50.0 | 56.6 |
| 50° | 85.0 | 88.6 | 66.5 | 71.7 | 53.0 | 58.7 |
| 55° | 83.5 | 86.0 | 62.0 | 70.0 | 52.5 | 60.3 |
| 58° | | | | | 48.5 | |
| 60° | 79.5 | 83.7 | 54.5 | 66.0 | 44.5 | 56.4 |
| 65° | 71.7 | 79.6 | 45.7 | 60.0 | | |

Table II. gives the percentage of light transmitted by 1, 4, and 10 plates for different values of $i$. The first column gives the values of $i$; the second, fourth, and sixth columns give the observed amounts of light transmitted; and the third, fifth, and seventh columns give the theoretical amounts. These last were calculated from the formula $t = \frac{1}{2}\left(\frac{1-A}{1+(m-1)A} + \frac{1-B}{1+(m-1)B}\right)$, in which $A$ was determined from the equation $A = \frac{\sin^2(i-r)}{\sin^2(i+r)}$, and $B$ from the equation $B = \frac{\tan^2(i-r)}{\tan^2(i+r)}$, by substituting the proper values for the angles of incidence and refraction, assuming the index of refraction to be 1.55. Constructing the points, with abscissas equal to the angles of incidence and ordinates to the observed amounts of light transmitted, it will be found that they form very smooth curves. But it will be noticed that while they agree in general with the theoretical results, assuming that the light is lost by simple specular reflection, the differences are considerable, showing that we ought not in our calculation to neglect the opacity of the glass, imperfection of the surface, and other sources of error.

From the numbers in this table, we conclude that, while the amount of light transmitted by one plate decreases considerably as $i$ increases, the amount transmitted by four plates is more nearly constant for small angles, and the amount transmitted by ten plates actually increases until $i$ becomes 55°; which facts agree with the conclusions arrived at theoretically by Prof. Pickering. (Proc. Amer. Acad. Vol. IX. p. 6.)

It was impossible to carry these experiments beyond $i = 65°$ with the apparatus employed, because the disc came so near the mirror as to cast a shadow upon itself.